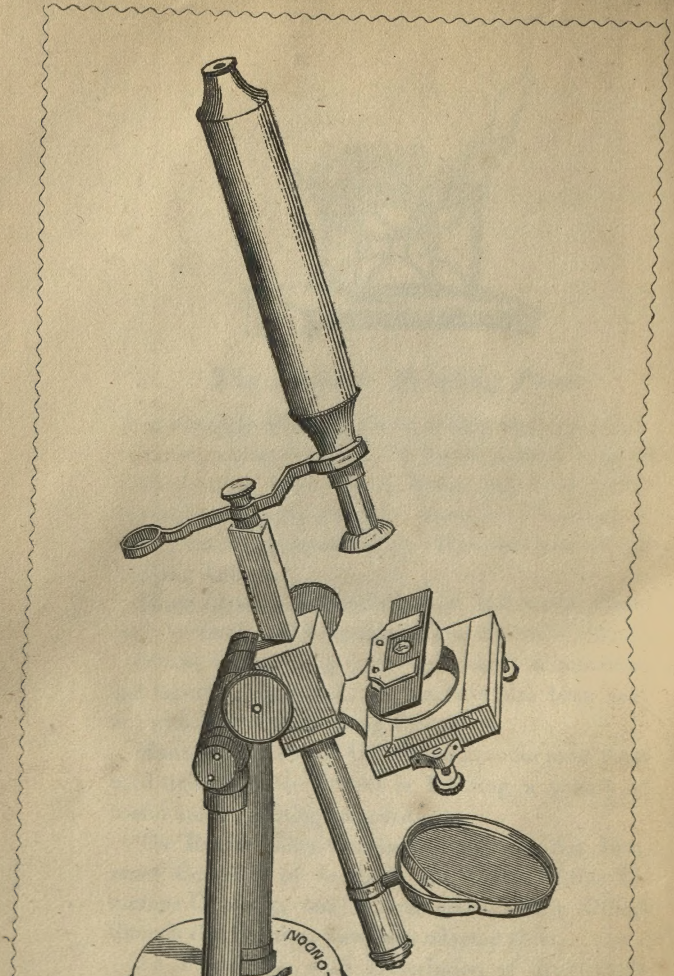
WILLATS.LONDON

63.5

MICROSCOPIC MANIPULATION;

CONTAINING

THE THEORY AND PLAIN INSTRUCTIONS

FOR THE USE OF

THE MICROSCOPE,

INCLUDING

THE BEST METHODS FOR THE MOUNTING OF OBJECTS, AND A REVIEW OF THE IMPORTANT DISCOVERIES EFFECTED BY THIS INSTRUMENT.

BY

GEORGE THOMAS FISHER, JUN.

AUTHOR OF "PHOTOGENIC MANIPULATION," "A TREATISE ON MEDICAL ELECTRICITY," ETC.

ILLUSTRATED BY WOOD-CUTS.

LONDON:

THOMAS & RICHARD WILLATS, OPTICIANS,

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AND ALL BOOKSELLERS.

1846.

TO

JOHN P. GASSIOT, ESQUIRE,

F. R. S., ETC., ETC., ETC.

This little Work

IS MOST RESPECTFULLY DEDICATED,

AS A HUMBLE THOUGH GRATEFUL AND SINCERE ACKNOWLEDGMENT FOR MANY ACTS OF KINDNESS RECEIVED AT HIS HANDS,

BY HIS OBEDIENT SERVANT,

GEORGE THOMAS FISHER.

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INTRODUCTORY REMARKS.

1. Of all philosophical instruments there are certainly none which are more interesting, or which present greater claims to our admiration than the Microscope.* Wherever we turn, within the precincts of our own homes—in meadow or moorland, hill or forest, by the lone seashore or amidst crumbling ruins—fresh objects of interest are constantly to be found;—plants and animals, unknown to our unaided vision, with minute organs perfectly adapted to their necessities; with appetites as keen, enjoyments as perfect as our own. In the purest waters, as well as in thick, acid, and saline fluids, of the most indifferent climates,—in springs, rivers, lakes, and seas,—often in the internal humidity of living plants and animals,—even in great numbers in the living human body—nay, probably carried about in the aqueous vapours and dust of the whole atmosphere—there is a world of minute, living, organised beings, imperceptible to the ordinary senses of man. In the daily course of life, this immense mysterious kingdom of diminutive living beings is unnoticed and disregarded; but it appears great and astonishing beyond all expectation, to the retired observer, who views it by the aid of the microscope. In every drop of standing water, he very frequently, though not always, discovers by its aid rapidly moving bodies, from 1-96 to less than 1-2000 of a line in diameter, which are often so crowded together that the intervals between them are less than their diameter. If we assume the size of the drop of water to be one cubic line, and the intervals, though they are often smaller, to be equal to the diameter of the bodies, we may easily calculate, without exaggeration, that such a drop is inhabited by, from one hundred thousand to one thousand millions of such animalculæ; in fact, we must come to the conclusion, that a single drop of water, under such circumstances, contains more inhabitants than there are individuals of the human race upon our planet. If further, we reflect on the amount of life in a

* From μικρος *small*, and σκοπεω *to observe*.

large quantity of water, in a ditch or pond, for example; or if we calculate, that according to many observers of the sea, and especially of its phosphorescence, vast tracts of the ocean periodically exhibit a similar development of masses of microscopic organised bodies; even if we assume much greater intervals; we have numbers and relations of creatures living on the earth, invisible to the naked eye, at the very thought of which the mind is lost in wonder and admiration. It is the microscope alone, which has enabled close observers of nature to unveil such a world of her diminutive creation, just as it was the art of making good telescopes which first opened to their view the boundless variety and all the wonders of the starry firmament.

2. But it is not here that the utility or interest of the microscope ceases. To the botanist, the zoologist, the geologist, and the physiologist it is equally valuable, equally indispensable. By its aid may we examine the minute structure of the organs and tissues of which plants and animals are made up,—by it discover the links which bind the vegetable to the animal kingdom,—by it are we enabled to ascertain the nature of the vegetation which decked the earth, long ere man "moved, and breathed, and had his being;" and by it may the anatomist discover the structure in health, and the derangement from disease of the various organs of the body.

More recently the microscope has been brought to bear upon the fossil animals, which are constantly being discovered in all parts of the world. By a careful examination of sections of teeth and other bones, the classification of the animals to which they belonged, as made by geologists from other data, has in most instances been proved to be correct. "In the hands of an Owen and a Mantell, the microscope becomes an instrument of magic power; by means of which, from the inspection of a bone or a tooth, the colossal reptiles of the ancient earth are revived in all the reality of life and being, and the early formations of the earth peopled with their former inhabitants again." In medico legal enquiries, the microscope again comes to our aid in detecting the murderer, and rendering him back the poison grain for grain. Blood and other organic stains are by its means readily detected when all other methods have failed.

PLAIN INSTRUCTIONS

FOR

THE USE OF THE MICROSCOPE.

Chapter I.

HISTORY OF THE MICROSCOPE.

3. The History of the Microscope, like that of many other valuable inventions, has been veiled in considerable obscurity by the lapse of time. It seems pretty certain that the ancients were not unacquainted with the microscope, in one at least of those forms of which we shall have to speak, if we are to give credence to a passage in Seneca. "Letters," says he, "though minute and obscure, appear larger and clearer through a glass bubble filled with water." Amongst the moderns, (for during the middle ages it appears to have been entirely lost,) the honor of its discovery has been claimed by many individuals. By Huygens, the celebrated Dutch mathematician, its invention is attributed to one of his countrymen, named Drebell. Microscopes were constructed by him in the year 1521, that is to say shortly after the invention of the telescope. It is asserted by Borrelli, that Jansen, the reputed contriver of the telescope, was its inventor, and that he presented some such instruments to Prince Maurice, and Albert, Archduke of Austria. These instruments were six feet in length, and consisted of a tube of gilt copper, supported by thin brass pillars in the shape of dolphins, on a base of ebony, which was adapted to hold the objects to be examined. Of the internal construction of this microscope we have no account, though there is reason to believe that it was nothing more than a telescope converted into a microscope. Viviani,

an Italian mathematician, also expressly informs us, in his Life of Galileo, that this great man was led to the construction of the microscope from that of the telescope; and in the year 1612 he actually sent a microscope to Sigismund, King of Poland. In the year 1618, Fontana, a Neapolitan, made a microscope of two double convex lenses, and wrote an account of it in a work which he published in 1646.

For a long period, however, curious as the fact may now appear, the single microscope was that generally in use, and the compound instrument was considered as a mere philosophical toy, owing to the distance which the light had to traverse, and the consequent increase of the chromatic and spherical aberrations. Indeed so impossible did it appear to overcome this great difficulty, that within thirty years of the present period, philosophers of no less eminence than M. Biot and Dr. Wollaston predicted, that the compound would never rival the simple microscope, and that the idea of rendering its object-glass achromatic was hopeless. Nor can these opinions be wondered at, when we consider how many years the achromatic telescope had existed without any attempt to apply its principles to the compound microscope. When we consider the smallness of the pencil required by the microscope, and the enormous increase of difficulty attending every enlargement of the pencil; when we consider further, that these difficulties had to be contended with, and removed, by operations on portions of glass so small that they were themselves almost microscopic objects, we shall not be surprised, that even a cautious philosopher and able manipulator, like Dr. Wollaston, should prescribe limits to its improvement.

4. Fortunately, however, for science, and especially for the departments of animal and vegetable physiology, these predictions have been shown to be unfounded. The last fifteen years have sufficed to elevate the compound microscope from the condition we have described, to that of being the most important instrument ever bestowed by art upon the investigator of nature. It now holds a very high rank amongst philosophical instruments; while the transcendent beauties of form, colour, and organization which it reveals to us, in the minute works of nature, render it subservient to the most delightful and instructive pursuits. To these claims on our attention it appears likely to add a

third of still higher importance. The microscopic examination of the blood and other human organic matter, will, in all probability, more than ever it has yet done, afford satisfactory and conclusive evidence regarding the nature and seat of disease, than any hitherto appealed to; and will, of consequence, lead to similar certainty in the choice and application of remedies.

5. Soon after the year 1820, a series of experiments was begun in France, by M. Selligues, which were followed up by Frauenhofer, at Munich, by Amici, at Modena, by Chevalier, at Paris, and by the late Mr. Tulley, of London. In 1824, the last-named artist, without knowing what had been done on the continent, made an attempt to construct an achromatic object-glass for a compound microscope, and produced one of 9-10ths of an inch focal length, composed of three lenses, and transmitting a pencil of eighteen degrees. This was the first that had been made in England. While these practical investigations were in progress, the subject of achromatism engaged the attention of some of the most profound mathematicians in England. Sir John Herschel, Professor Airy, Professor Barlow, Mr. Coddington, and others, contributed largely to the theoretical examination of the subject; and though the results of their labours were not immediately applicable to the microscope, they essentially promoted its improvement. Between this period and the year 1829, Mr. Joseph Jackson Lister had directed his attention more particularly to this subject, and he was led to the discovery of certain properties in achromatic combinations which had been before unobserved. A paper on the subject was sent by him to, and published by, the Royal Society.* To the practical optician the investigations and results of Mr. Lister proved to be of the highest value; and the progress of improvement was in consequence extremely rapid, and since that period every year has brought this instrument nearer to perfection.

6. It would be foreign to the intentions of this work, to enter into any lengthened details of the optical principles involved in the construction of the microscope, or to trace out the various steps by which the chromatic and spherical aberration, which rendered the early instruments useless, have now been overcome. To the optician and the

* Philosophical Transactions, 1829.

actual manufacturer of the microscope alone would this information be of interest; and as this little Manual is intended rather for the use of the amateur and general reader, and has been written with the view of conveying a knowledge of the manipulation of the instrument, and the method of preparing and classifying objects for it, we shall content ourselves with a brief enumeration only of the optical principles on which it is constructed, dwelling more largely upon its use, and its wondrous revelations."*

CHAPTER II.

CONSTRUCTION OF MICROSCOPES.

7. The forms of microscopes are very numerous, but they may all be included in two distinct classes, however much they may vary as to their external appearances, viz. :—SINGLE MICROSCOPES, in which the object itself is magnified, whether by a single lens, or a combination of lenses; and COMPOUND MICROSCOPES, in which a magnified image of the object, not the object itself, is magnified.

8. To comprehend how it is that the lenses, which are used in the formation of all descriptions of microscopes, increase the size of objects, or magnify them, as it is termed, the reader must clearly understand what is meant by the apparent magnitude of objects. If a small coin be placed at the distance of a hundred yards from us, it will be scarcely perceptible; and its apparent magnitude, or the angle under which it is seen, is said to be then extremely small. At the distance of twenty or thirty yards we should just perceive that it was a round body, and that its apparent magnitude had increased; at the distance of three yards, we should begin to trace the effigy and inscription upon

* To those who may be desirous of studying this question more in detail, we would recommend for consultation, *Brewster's Treatise on Optics;* Article *Microscope, in the Penny Cyclopædia,* and the same Article in the 'Edinburgh Cyclopædeia,' and the 'Encyclopædeia Britannica.'

it; and at the distance of six or eight inches, its apparent magnitude is so great, that it appears to cover a distant object fifty or one hundred times its size. By thus bringing the coin nearer the eye, we have actually magnified it, or made it apparently larger, though its size remains the same. Again, as a further example of this: if we look at two men of the same height, the one 200 feet, the other 100 feet from us, the former will appear only half the height of the latter, or the angle which the latter subtends to the eye of the observer will be twice that of the former. Hence it becomes evident that the nearer we can bring an object to the eye the larger will it appear.

9. But let us suppose that the object be distant from us twenty feet, and let a convex lens, whose focal length is five feet, be placed half way between it and the eye, that is to say ten feet from each, then it is plain that the image of the object, as formed by the refracting power of the lens, will be exactly of the same size as the object, and consequently it is not directly magnified by the lens; but as the image is brought so near to us that the eye can view it at the distance of six inches, its apparent magnitude is increased in the proportion of six inches to twenty feet, or as one to forty,—that is forty times. It is, in fact, magnified forty times, merely by bringing an image of it nearer to the eye.

10. But if wehave to examine a very minute object, and in order to render its parts distinguishable we bring it very near to the eye, within an inch or two, for example, it will become very indistinct and confused. This effect is produced by the great divergence of the rays of light from the object, and the power of the chrystalline lens of the eye not being sufficient to collect the rays, whereby an image of the object may be formed on the retina, at the proper distance on the back of the eye. Now if we employ a convex lens, and place it between the object and the eye, the former being in the focus of the glass, the diverging rays from the object will be refracted and rendered parallel by the lens, and thus we shall obtain a distinct and near view of the object. If we place the lens close to the eye and the object, in such a way that the rays which flow from it may receive that precise degree of divergency which they had when the object is placed six inches from the eye, the nearest distance at which we see minute objects distinctly, if the dis-

tance be an inch, the object will have its apparent magnitude six times greater than when it is seen at the distance of six inches without the lens. It is therefore said to be magnified six times by the lens. This lens therefore is a single microscope, and the magnifying power of such microscopes may be always found by dividing six inches by the focal distance of the lens. A lens, for example the tenth of an inch in focal length, will magnify 60 times; and one the hundredth of an inch, 600 times.

11. Single Microscopes.—Single microscopes may consist, as we have already said, of one or more lenses, but in all cases it is the *object itself* which is magnified. The simplest form of single microscope is that which consists of a single lens or spherical globule, fitted up so that it may be conveniently held to the eye, the object being at the focus of the lens. A common hollow globe of glass an inch in diameter, and filled with water, is of itself a single microscope; so would be a drop of water, placed upon a hole drilled in a thin piece of brass. A lens is, of course, far preferable to either of these contrivances. For a variety of purposes, a single lens is an extremely useful instrument, and they are usually mounted by opticians in a number of ways for portability and convenience. Figs. 1 and 2 represent forms of single microscopic lenses, mounted in such a manner as to be folded up and carried in the pocket.

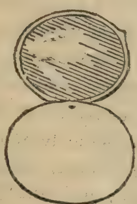


Fig. 1.

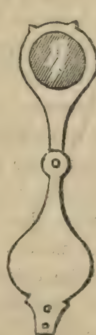


Fig. 2.

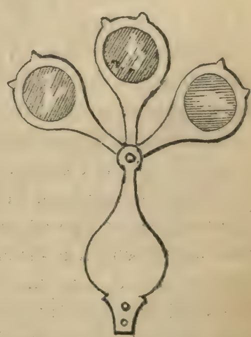


Fig. 3.

Fig. 3 is a useful combination of three lenses, mounted in a case of a convenient size for the pocket. By varying the arrangement of the lenses, or by taking each separately, it affords many degrees of magnifying power.

Fig. 4 and 5 represent other forms of microscopic lens, much in use for the examination of linen cloth, and for ascertaining the number of threads in a given space.

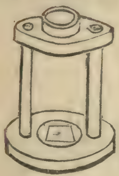


Fig. 4.

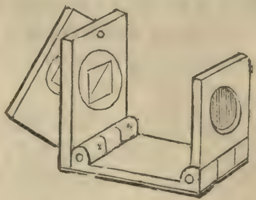


Fig. 5.

12. Stanhope Lens.—But, perhaps, the most powerful of these simple lenses is that invented by Lord Stanhope. It is a double convex lens, the end however which is nearest to the eye being ground more convex than the other, in the proportion of three to five. It is set in a metal cylinder, the length of which is the exact focus of the lens, and thus it possesses great advantages over every other form of common lens. By it all difficulty of retaining the instrument to the exact focus, and the loss of light and small field are obviated. The object to be examined has only to be placed on the less convex end of the lens, or to be brought in contact with it, when the advantage of great magnifying power and a field of nearly five inches are obtained. Its general form is represented in the annexed figure.

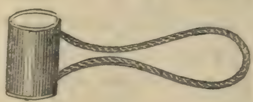


Fig. 6.

So powerful are these lenses that many interesting objects may be

distinctly seen by them,—such as animalcules in water, mites in cheese, hairs of animals, down of moths, etc.; and the process of chrystallization may also be conveniently watched with them.

13. Coddington's Lens.—Of these simple lenses, the best unquestionably for viewing opaque objects, chrystals, etc. is that which has, from its inventor, been denominated the Coddington lens. It is a small sphere of glass, with its equatorial parts ground away that it may at the same time magnify and yet be corrected for spherical aberration. These lenses are sold by all optical instrument makers. In external form they resemble the Stanhope lens.

14. A frequent and most convenient form of simple microscope, is that which is represented in the annexed woodcut, and which has the advantage of great portability. From the arrangement of the mountings to suit the nature of the objects to be examined, these microscopes often derive their name, though the principle of all of them is similar—as botanical, mineralogical, anatomical, natural history, aquatic microscopes. A is a piece of thick brass, with a channel cut along it to enable B to slide along it. The arm A being jointed, is capable of lying flat when out of use, or can be altered to suit any other convenient position. B is a brass pillar terminated by a pair of nippers C, for holding the objects to be examined; D is a brass socket and screw holding the lens, which may be thus changed for another, if it be desirable; E is the handle to hold the instrument, which may be unscrewed at the lower half, and thus rendered exceedingly compact. There are often in the socket D two lenses, one at each side. These two lenses, when low power is wanted, as in the inspection of flowers, are frequently two plano-convex lenses with their plain sides turned towards the eye. The advantages of this combination are, an increase of field and the diminution of

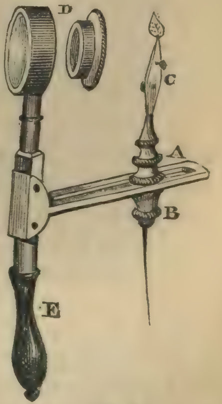


Fig. 7.

aberration. The focal distances of the lenses mounted in the single microscopes, are usually $1\frac{1}{2}$-inch, 1-inch, $\frac{1}{2}$, $\frac{1}{4}$, 1-16th, 1-20th of an inch.

15. But the most perfect form of single microscope is that which is represented in the annexed diagram, and which, as far as its power extends, is suitable for the examination of any kind of object. It consists of a circular brass stand, capable of being fixed in every possible inclination by the ball C attached to the clamp B, by which the whole may be firmly fixed to a board or table; the circular mirror D working in the arm M is attached to the tube X in the usual way. The whole slides upon the stem, that it may be placed nearer to or farther from the object, according to the intensity of the light required for the various objects under examination. The back of this reflector is flat and polished, so that a monochromatic light reflected from the brass may be employed when necessary.

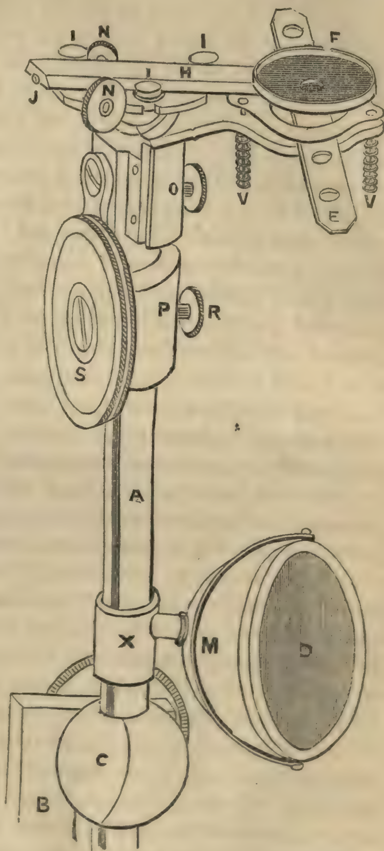


Fig. 8.

The lenses are mounted in cells as shown at F, and are screwed into the dovetail bar H, sliding between three stout pins I I I, the nearest one having a strong pin on the under side which keeps the bar in close contact with the other two without any shake. The bar is moved across the object by either of the nuts N N, which instead of having a pinion, as usual, have a spring wound round their axis attached at each end to the bar H, with an adjusting screw to regulate the tension at the end J; the bar may also be turned round on the central pin fitted in the top of the stem A, and thus a traversing motion in every direction may be given to the bar and lens, without disturbing the object or altering in the least the distance between it and the lens. The adjustment of the focus is first made by sliding the stage pieces O P by the hand until the object is seen nearly distinct, the thumb screw R being then turned, fixes the lower piece P to the stem A; then by means of the large milled head S, the final adjustment is made by the intervention of a connecting bar T attached to the stage piece; this bar works on an elastic eccentric movement under the milled head S, so that an adjustment of any small quantity can be obtained with extreme precision. The slider containing the object is kept close to the stage by two heliacal springs V V. A condensing lens and a pair of forceps are made to fit in the piece O, and can be employed with or without the stage-plate, which may be entirely removed by the thumb-screw in front when necessary.

We have been thus particular in the description of single microscopes, although their use in the present day is extremely limited, for two reasons,—first, because a perfect comprehension of that instrument better enables us to understand the principles of the more perfect apparatus, the compound microscope; and, secondly, because such instruments are still in use, and this Manual would therefore have been incomplete without such a description. For certain kinds of botanical specimens, the single microscopes are exceedingly useful. Figures 9 and 10 represent two forms of botanical microscopes, which however require no very extended explanation. The latter instrument, fig. 10, is indeed a very superior apparatus, both from its portability and exceedingly moderate price. It is fitted with good object and eye-glasses, as well as with a mirror, which can be turned to any required angle. It may also be obtained, fitted with additional powers

and with condensing lens attached by a moveable arm. I have one of these latter instruments, made by Messrs. Willats, in my possession, and find it extremely useful for the generality of botanical objects, and indeed for the examination of any specimens where no very great power is required.

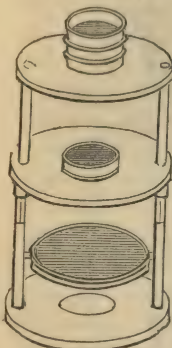


Fig. 9.

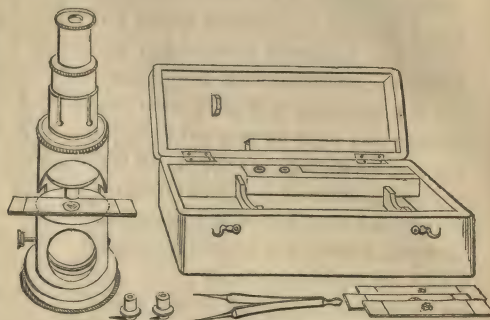


Fig. 10.

16. Compound Achromatic Microscope.—In a treatise like the present, it would be utterly impossible for us to enter into any lengthened details concerning the optical principles involved in the construction of these beautiful instruments, or of the means taken by the optician to correct the chromatic and spherical aberration of the lenses. We must again refer such of our readers who desire to become practically acquainted with the subject, to those treatises of which we have already spoken. (P. 18.)

The annexed engraving (fig. 11) will show the general construction of the form of achromatic microscopes. O is the triple achromatic object-glass. F is a plano-convex lens, called the field-glass, situate in the tube of the microscope, and E E is the eye-glass. These together form the modern microscope. The course of the light is shown by drawing three rays from the centre, and three from each end of the object O. These rays would, if left to themselves, form an image of the object at A A; but being refracted by the field-glass of F F, they form the image at B B, where a stop is placed to intercept all light, except what is required for the formation of the image. From B B therefore the rays proceed to the eye-glass,

exactly as has been described in reference to the single microscope and to the compound of two glasses.

17. Having thus briefly explained the optical principles of the achromatic compound microscope, it remains only to describe the mechanical arrangements for giving those principles effect. The mechanism of a microscope is of much more importance than might be imagined by those who have not studied the subject. In the first place, steadiness or freedom from vibration, and most particularly steadiness or freedom from any vibrations which are not equally communicated to the object under examination, and to the lenses by which it is viewed, is a point of the utmost consequence. When, for instance, the body containing the lenses is screwed by its lowest extremity to a horizontal arm, we have one of the most vibratory forms conceivable; it is precisely the form of the inverted pendulum, which is expressly contrived to indicate otherwise insensible vibrations. The tremor necessarily attendant on such an arrangement, is magnified by the whole power of the instrument; and as the object on the stage partakes of this tremor in a comparatively insensible degree, the image is seen to oscillate so rapidly, as in some cases to be wholly undistinguishable.

One of the best modes of mounting a microscope is shown in the annexed plate, by a reference to which the reader will be enabled to understand the chief features of the arrangements. (Fig. 12.)

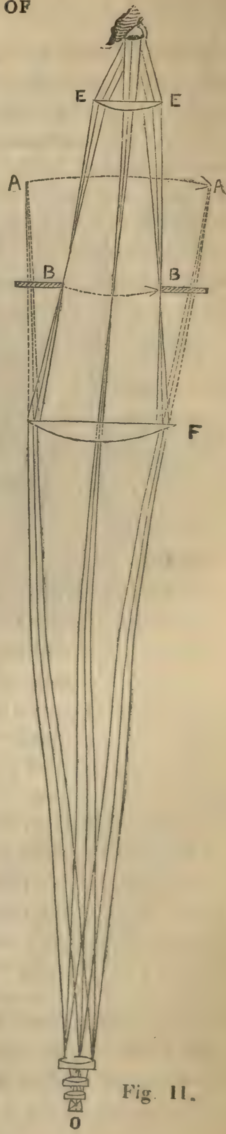


Fig. 11.

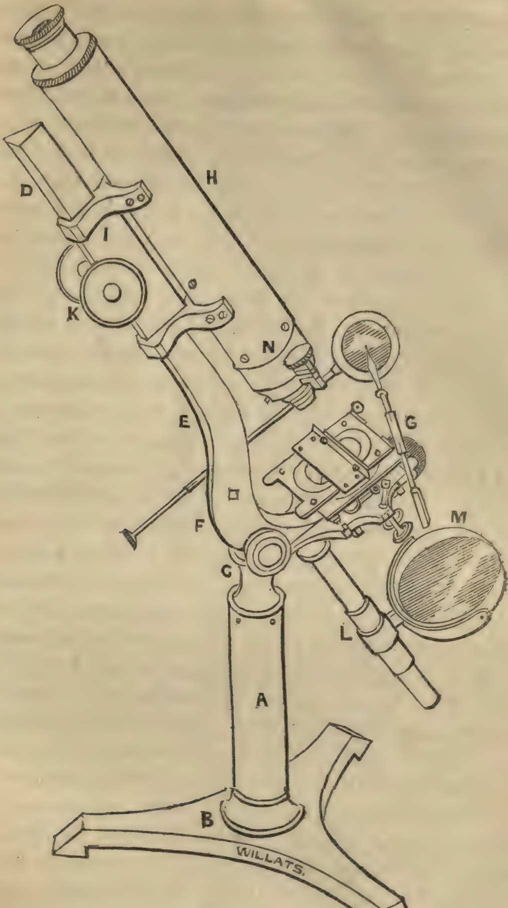


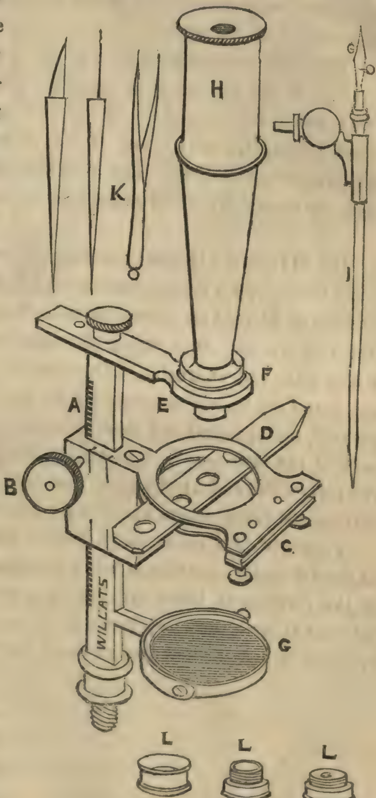
Fig. 12.

A massy pillar A is screwed into a solid tripod B, and is surmounted by a strong joint at C, on which the whole instrument turns so as to enable it to take a perfectly horizontal or vertical position, or

any intermediate angle; such, for example, as that shown in the engraving. This moveable portion of the instrument consists of one solid casting, D, E, F, G; from F to G being a thick pierced plate, carrying the stage and its appendages. The compound body H is attached to the bar D E, and moves up and down upon it by a rack and pinion worked by either of the milled heads H. The piece D, E, F, G, is attached to the pillar by the joint E, which being the source of the required movement in the instrument, is obviously its weakest part, and about which no doubt considerable vibration takes place. But inasmuch as the piece D, E, F, G, of necessity transmits such vibrations, equally to the body of the microscope and to the objects on the stage, they hold always the same relative position; and no visible vibration is caused, how much soever may really exist. To the under side of the stage is attached a circular stem L, on which slides the mirror M, plane on one side and concave on the other, to reflect the light through the aperture in the stage. Beneath the stage there is generally a circular revolving plate containing three apertures of various sizes, to limit the angle of the pencil of light which shall be allowed to fall on the object under examination. This is called the diaphragm. Besides these conveniences, the stage has a double movement, produced by two racks at right angles to each other, and worked by milled heads beneath. It has also the usual appendages of forceps to hold minute objects, and a lens to condense the light upon them; all of which are generally understood; and if not, will be rendered more intelligible by a few minutes' examination of a microscope than by the most lengthened description. One other point remains to be noticed. The movement produced by the milled head K is not sufficiently delicate to adjust the focus of very powerful lenses, nor indeed is any rack movement; only the finest screws are adapted for this purpose, and even these are improved by means for reducing the rapidity of the screw's movements. For this purpose, the lower end of the compound body H, which carries the object-glass, consists of a piece of smaller tube sliding in parallel guides in the main body, and kept constantly pressed upwards by a spiral spring; but it can be drawn downwards by a lever crossing the body, and acted on by an extremely fine screw, whose milled head is seen at N, and the fineness of which is tripled by means of the lever, through which it acts upon

the object-glass. The instrument, of course, is roughly adjusted by the rack movement, and finished by the screw, or by such other means as are chosen for the purpose.

A more recent and more compact form of this instrument is represented in the frontispiece; but as the difference of construction will be seen by a reference to the engraving, no more lengthened detail is needed. It is the most modern form of instrument, and possesses the advantage of a greater compactness and steadiness, from its being supported on two pillars in lieu of one. This instrument is perhaps the best adapted for educational purposes, from its not being so liable to get out of order.



Figs. 13 and 14.

Gould's Microscope.—A very convenient and powerful form of instrument is that which bears the above name. Its general form is as in the annexed diagram, and the whole fits into a mahogany box.

In the centre of the lid of the box screws the upright square stem A, fig. 14. This has upon one side of it a rack movement, in which works the screw B, intended to raise or de-

press the stage C, as occasion requires. C consists of two plates of brass held together by a spring; between these plates the object slider D is placed. E is an arm at right angles to A; it is attached and confined by the screw at the end of it in A. F must be supposed to represent three lenses, or magnifiers, screwed together, the focus of each being such that they act in unison together. G is a reflector to cast the light upwards through the object to the eye. H is the main tube, which bears the eye-lens at one end, and screws upon one of the object lenses at the other.

When the instrument is in use, the focus is adjusted by moving the screw B, and the degree of magnifying power is according to the lenses, which are screwed on to the bottom of H. Thus, if one lens obtain an increase of 10, two lenses may obtain a power of 100, and three lenses of 1000. Let it be always remarked, that the more lenses the more obscure will be the image.

18. Medical Achromatic Microscope.—Another form of compound microscope is represented in the following outline, (fig. 15.) It is particularly adapted for the examination of anatomical and physiological preparations, and from being less complicated in its arrangements is also much less expensive. The stout stand 3 is screwed into the foot 4, and the body 1 is supported by the arm 2. The object-glasses are at 5, the eye-glass and field-glass are of course contained in the body of the instrument; 6 is the moveable stage, and 7 the mirror. The portability, and at the same time high magnifying power of these instruments, renders them exceedingly useful.

Figure 16 is a more recent form of the same instrument; but as its chief difference consists in being arranged in such a way as to allow of the instrument being brought into any convenient position by the joint at 3, no more lengthened detail is requisite. Its internal construction is essentially the same as the former.

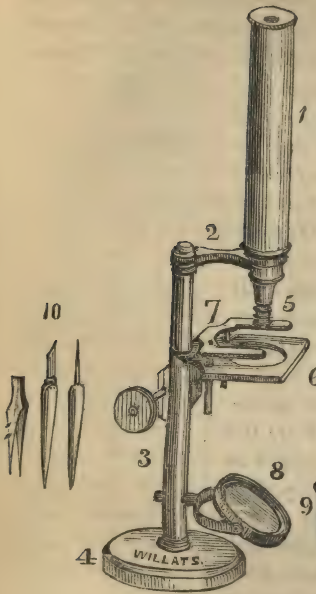


Fig. 15.

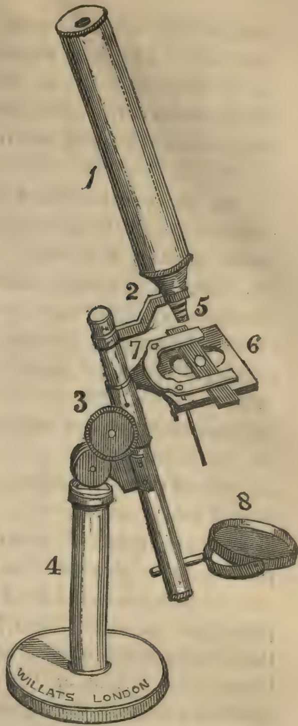


Fig. 16.

19. Method of Measuring the Magnifying Power of Microscopes.—We purpose in the next place to explain the method of ascertaining the magnifying power of the compound microscope; and we are the more anxious to do this, for the reason that it is a fault too common amongst the makers of these instruments to exaggerate the power of the apparatus. The mode of measuring the magnifying power of the compound microscope is generally taken at the assumption, that the naked eye sees most distinctly at the distance of ten inches. Place on the stage of the instrument, a known divided scale; and when it is distinctly seen, hold a rule ten inches from the dis-

engaged eye, so that it may be seen by that eye, overlapping or lying by the side of the magnified picture of the other scale. Then move the rule till one or more of its known divisions correspond with a number of those in the magnified scale, and a comparison of the two gives the magnifying power.

20. Micrometer Eye-Piece.—The micrometer eye-piece is in many instances a very useful apparatus, and is the invention of a Mr. Ramsden. When it is stated, that we sometimes require to measure portions of animal or vegetable matter a hundred times smaller than any divisions that can be artificially made on any measuring instrument, the advantage of applying the scale to the magnified object will be obvious, as compared with the application of engraved or mechanical micrometers to the stage of the instrument.

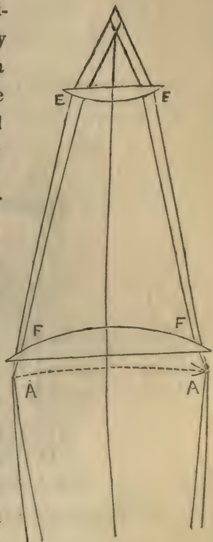


Fig. 17.

The arrangement is shown in the accompanying figure, where E E and F F are the eye and field-glasses, the latter having now its plane face towards the object. The rays from the object are here made to converge at A A immediately in front of the field-glass, and here also is placed a plane glass, on which are engraved divisions of 1-100th of an inch, or less. The markings of these divisions come into focus therefore at the same time as the image of the object, and both are distinctly seen together. Thus the measure of the magnified image is given by mere inspection, and the value of such measures in reference to the real object may be obtained thus; which, when once obtained, is constant for the same object-glass. Place on the stage of the instrument a divided scale, the value of which is known, and viewing this scale as the microscopic object, observe how many of the divisions on the scale attached to the eye-piece correspond with one of those in the magnified image. If, for instance, ten of those in the eye-piece correspond with one of those in the image, and if the divisions are known to

be equal, then the image is ten times larger than the object, and the dimensions of the object are ten times less than indicated by the micrometer. If the divisions in the micrometer and in the magnified scale be not equal, it becomes a mere rule-of-three sum; but in general this trouble is taken by the maker of the instrument, who furnishes a table showing the value of each division of the micrometer for every object-glass with which it may be used.

Chapter III.

ON THE METHOD OF VIEWING AND ILLUMINATING MICROSCOPIC OBJECTS.

21. The art of illuminating microscopic objects is not of less importance than that of preparing them for observation. No general rules can be given for adjusting the intensity of the illumination to the nature and character of the object which is to be examined; and it is only by a little practice that this art can be acquired. In general, however, it will be found that very transparent objects require a less degree of light than those which are less so: and that objects which reflect white light, or which throw it off from a number of lucid points, require a less degree of illumination than those whose surfaces have a feeble reflective force.

Most opticians have remarked, that microscopic objects are commonly seen better in candle-light than in daylight, a fact which is particularly apparent when very high magnifying powers are employed; and we have often found, that very minute objects, which could scarcely be seen at all by daylight, appeared with tolerable distinctness in candle-light. An argand lamp, of somewhat peculiar construction, as represented in the accompanying figure 19, is therefore usually employed. It is made so that the body can be raised or depressed at pleasure, and fixed by a screw. Over the chimney-glass a tube of blackened tin is fitted, so as to allow the light only to pass through a single aperture. A large detached lens also, moving on a slide (fig. 20) is sometimes used to throw parallel rays upon the mirror, and this is generally looked upon as the best artificial light.

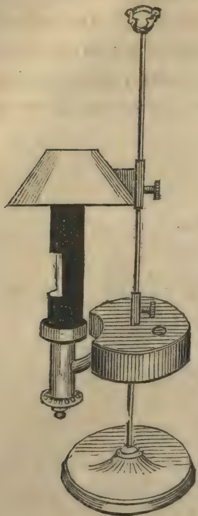


Fig. 19.

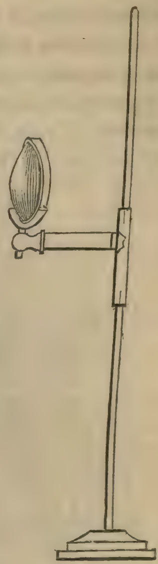


Fig. 20.

22. The following rules, as given by Brewster, may be laid down respecting the illumination of microscopic objects, and the method of viewing them:—

1. The eye should be protected from all extraneous light, and should not receive any of the light which proceeds from the illuminating centre, excepting that portion of it which is transmitted through or reflected from the object.

2. Delicate microscopical observations should not be made when the fluid, which lubricates the cornea of the observer's eye, happens to be in a viscid state, which is frequently the case.

3. The figure of the cornea will be least injured by the lubricating fluid, either by collecting over any part of the cornea, or moving over it when the observer is lying on his back, or standing vertically. When he is looking downwards, as into the compound vertical micro-

scope, the fluid has a tendency to flow towards the pupil, and injure the distinctness of vision.

4. If the microscopic object is longitudinal, like a fine hair, or consists of longitudinal stripes, the direction of the lines or stripes should be towards the observer's body, in order that their form may be least injured by the descent of the lubricating fluid over the cornea.

5. The field of view should be contracted, so as to exclude every part of the object, excepting that which is under his immediate examination.

6. The light which is employed for the purpose of illuminating the objects, should have as small a diameter as possible. In the day time it should be a single hole in the window-shutter of a darkened room, and at night it should be an aperture placed before an argand lamp.

7. In all cases, and particularly when very high powers are requisite, the natural diameter of the light employed should be diminished, and its intensity increased by optical contrivances.

23. As the whole subject of the illumination of objects is of the most important character, I shall make no apology for quoting the remarks of an able microscopist on the subject.* "Much of the beauty," he remarks, "of the objects seen depends upon the management of the light that is thrown upon or behind them, which can only be fully mastered by practice. It may be remarked, however, as a general rule, that in viewing those which are transparent, the plane mirror is most suited for bright daylight, the concave for that of candle or lamp-light, which should have the bull's-eye lens, when that is used, so close to it, that the rays may fall nearly parallel on the mirror; if the bull's-eye lens be not used, the illuminating body should not be more than three inches from the object, the details of which are usually best shown when the rays from the mirror fall upon it before crossing; and the centre should, especially by lamp-light, be in the axis of the body of the microscope. For obscure objects, seen by transmitted light, and for outline, a full central illumination is commonly best; but for seeing delicate lines, like those on the scales of insects, it should be

* Mr. J. Smith, 'Microscopic Journal,' vol. i. p. 48.

made to fall obliquely, and in a direction at right angles by the lines to be viewed.

"The diaphragm is often of great use in modifying the light and stopping such rays as would confuse the image; but many cases occur when the effects desired are best produced by admitting the whole from the mirror.

"The most pleasing light for objects in general is, that reflected from a white cloud on a sunny day; but an argand lamp or wax candle, with the bull's eye lens, is the best substitute."

24. Transparent and Opaque Objects.—It is generally known that objects for the microscope are sometimes prepared as transparent, at others as opaque objects. In the former instance the light reflected from the mirror is made to traverse, or rather to pass directly through the object; it is, in fact, viewed by transmitted light. In the latter, the light is thrown directly on the object. This may be accomplished in one or other of two ways. By one method a lens fixed to the stage is made to collect the rays of light, and thus to direct them on to the object; in the other the light is thrown up from the mirror on to the metallic specula attached to the object-glasses, (called from their inventor Lieberkhuns,) from which is reflected into the object. A large proportion of opaque objects are seen perfectly well (especially by day-light) with the side illumination; and for showing irregularities of surface, this lateral light is sometimes the best; but the more vertical illumination of the Lieberkhun is usually preferable, the light thrown up to it from the mirror below being, with good management, susceptible of much command and variety.

25. On Viewing Objects by Polarized Light.—The addition of a polarizing apparatus to a microscope is an excellent accompaniment to the instrument, whether we consider its peculiar properties, or the brilliant colours it gives to all bodies affected by it. Mr. Pritchard contrived a very simple apparatus for this purpose; it may readily be attached to or removed from the microscope, without either disturbing it or the object under consideration. It consists of two small tubes containing single-image calcareous prisms, or plate of tourmaline, and it is to be used in the same manner as plain diaphragms.

An intense light is to be directed through it, and the instrument adjusted to the object in the usual way, which will present the same appearance as without the tube of prisms. If, however, the second tube be placed near the eye, and close to the eye-glass, the object will appear of the most brilliant colours, if affected by polarized light.

When an object under examination exhibits the colours by depolarizing the light, if the field of view appear luminous, as in viewing transparent objects by common light, cause the eye-piece with its prism-tube to revolve; and in certain positions, the field of view will appear black—the objects assuming at the same time the complimentary colours, and appearing like brilliant gems lying upon black velvet. Many crystals exhibit these polarized tints very intensely. The following, crystallized on a slip of glass, are remarkably interesting, both as regards the elegance of their form and the splendour of their colours. Chlorate of potash, oxalic acid, prussiate of lime, nitrate of potash, and acetate of copper. The great advantage of employing the microscope in viewing the polarized tints of bodies is, that very small specimens will answer equally well with larger and more expensive ones in the ordinary way; and that they do not require any troublesome processes to cut them of different thicknesses for obtaining the different tints, this being accomplished in the process of the chrystallization.

26. Mr. Talbot has directed his attention to this subject; and as the experiments he has published are exceedingly interesting, and may readily be repeated, I have subjoined some of them :—

Sulphate of copper, which is of a fine blue colour when viewed in considerable thicknesses, is white and transparent when it is extremely thin, and its chrystals can be procured so small as to be quite destitute of perceptible coloration. A drop of its solution was placed upon a warm piece of glass, and suffered to evaporate gradually. The crystals shooting out from the edge of the drop into the interior of the liquid had a long and narrow rectangular form, with a slanting extremity, which may be compared in shape to the straight end of a chisel. Seen by common light, these crystals offer nothing peculiar; but on the darkened field of the polarizing microscope, they are luminous and splendidly coloured, the colour depending upon the thickness of the

crystal, and being the same in all points of its surface, except upon the little inclined plane which forms its extremity; but upon oblique portions are seen three or four distinct bands of colour parallel to the edge, and offering to the eye a visible scale or measure of the rapid diminution of thickness in that part. The observed succession of colours in one experiment was the following—yellow, brown, purple, blue, sky-blue, straw-yellow, pink, green, bluish green, pink.

Sulphate of copper, with a drop of nitric æther added to the solution, on a slip of glass, produced minute crystals in the form of rhomboids. These, when placed under the microscope with the field dark, appear like an assemblage of brilliant rubies, topazes, emeralds, and other gems, each being of a different thickness, depolarizing the light in a different degree. If the polarizing eye-piece be now turned a quarter round, the field becomes luminous, and the crystals assume the complimentary colours. Many other salts offer interesting results. Some, however, crystallize in such thin plates, that they do not sufficiently depolarise the light to become visible in the dark ground, such as the minute crystals of sulphate of potash precipitated by æther; but even these may be often rendered visible when placed on a plate of mica. The beautiful property of dichroism, discovered by Sir D. Brewster, in acetate of copper, may also be exhibited without any trouble, with the polarising microscope.

Many organic ,substances appear luminous when the field is darkened, while others are inert, having no sensible action on the polarized light.

Fragments of coarsely-powdered sugar and of various salts appear more or less bright, and mottled with various colours. Common salt remains dark, and does not act upon the light.

27. Test Objects.—It is perhaps one of the greatest requisites in the selection of a microscope, to be able to ascertain whether it will be efficient for the purposes intended. This can only be known by its capability of exhibiting those objects submitted to it. Till very recently it was not ascertained that certain objects, in order to render their various markings or texture distinctly apparent, required the instrument to be of the best construction, whether single or compound, and possessing a considerable quantity of distinct light. These objects

have therefore been denominated tests, by their discoverer Dr. Goring. In order that the reader may be able justly to appreciate the efficiency of any microscope that may come within his observation, and determine its penetrating and defining powers, whether the instrument be single or compound, I shall describe the principal test objects necessary for that purpose. The objects best adapted to determine the penetrating power are the dust or scales from the wings of certain classes of papilio, (butterflies and moths.) Of these, the *menelaüs*, shown in figures 21 and 25 of the following illustration, is a very useful object. The dust from the under side of the wing of the male papilio brassica, (white cabbage butterfly,) shown in fig. 22, is a good proof object; and a very peculiar one of the same kind is shown in fig. 24, (both magnified.) In viewing these objects, a large angle of aperture is required, (at least equal to half the focus,) in order that the lines and markings may be distinctly seen.

Fig 21. Fig. 22. Fig. 23. Fig. 24. Fig. 25.

There are, however, many of the scales from some kinds of papilio. on any of which the lines can be seen by an ordinary instrument. But the objects here selected, as well as the lines on the scales of the small brown house moth; the lines on the scales, taken from the foreign curculio, (diamond beetle,) fig. 23, require a more perfect instrument to develope them.

Mr. Pritchard recommends for this purpose, the scales from the wing of the Euplœa limniace, and the blue ones from the Papilio Paris as valuable objects, as the cross striæ on them are strongly and easily developed under a power of from 100 to 200 times linear.

Lastly—The most difficult of all the test objects, are the lines on

the scales from the *podura springtail*, discovered by Mr. T. Carpenter, and on which the scales are only just discovered by the most perfect instruments. When the penetrating power is thus ascertained, its defining power may be determined, by inspecting a leaf of the moss of a species of the genus *hypnum*, which requires a considerable penetrating as well as defining power fully to develop the hexagons which constitute its fabric, making out a luminous nucleus to each which should be sharply defined; and of the same shape with the outer hexagon. As opaque test objects, the bat's hair shown in figs. 26 and 27, and the mouse hair, figs. 28 and 29, may be considered excellent tests, when the markings and outlines are well defined. These objects may be also examined with transmitted light with the same advantages.

Fig. 26. Fig. 27. Fig. 28. Fig. 29.

28. The white letters on a black ground, seen on a piece of enamelled watch plate, is perhaps one of the best tests to determine the quantity of chromatic or spherical aberration in a lens; indeed, to detect the latter error, an artificial star is perhaps the best thing, as it requires considerable defining power to show well. The artificial star may be made by taking a very small globule of pure mercury kept in gum-water, and securing it to a black ground, as burnt cork or black paper, or a globule of platina fused by electricity, and attached to a black ground.

29. In examining these test objects, the direction and quantity of light must be carefully attended to, nor must it be injured or mutilated by the reflector, condensing lens, or other diaphonous body through which it may pass to the object. When an instrument can show these proof objects, it may with certainty be pronounced effective. It

should be remarked, that when the objects are used as opaque, a smaller aperture will do best, namely—about two-fifths of its focus. For transparent objects, a larger aperture is absolutely necessary; and for some tests it should be equal to its focal distance, to show the cross striæ between the lines on many of the scales when the power of the instrument or lens is considerable. It is worthy of remark, that the same aperture that with advantage will develop one class of objects will not show another with the same success.

30. As a conclusion to the subject of test objects, I shall quote the valuable remarks of Mr. Pritchard, in a little work published some time since:—"It cannot too strongly be impressed upon an observer, that of two instruments, the one which shows the object with the least power is always the best. This, of course, will not suit the lovers of the marvellous, who would rather see a flea appear as big as an elephant, though they lost all its finer markings, than have them preserved when moderately magnified. Another class of observers, who admire high powers for the microscope, are those whose sight is so defective that they cannot otherwise see a very minute object."

Chapter IV.

MICROSCOPIC OBJECTS AND THEIR MOUNTING.

31. Every department of nature is full of objects, from the examination of which the most important discoveries have already been and still may be expected to be made. But though the zealous observer can never be at a loss for subjects of research, it is desirable to know what has been done by our predecessors, and what trains of enquiry are likely to prove of the most general interest; for it is more particularly for the use of the general examiner that this little treatise has been written. It may, however, be again necessary to remind the reader, that as the work is intended only as a practical guide to the microscopical student, it is not the intention of the author to enter

into any details concerning the natural history of the objects described or named.

32. TRANSPARENT OBJECTS.—The general method of preserving these objects in a dried state, is between very thin plates of talc or mica fitted into cells formed in ivory sliders, having a split ring of wire to secure them, as in the following outline, (fig. 30.) The bottom of the cells should be turned quite flat to afford a good bearing for the mica, and of sufficient thinness to permit the magnifiers to approach the object. In using these sliders, like everything else, there is a wrong and a right side, which must be observed, or the student will not be able to approach close enough to the object with the high powers. The ring side should always be placed downwards, or from the microscope, and the other side next the eye or instrument. The softness of mica prevents its being cleaned like glass; it should therefore be kept as free as possible from dust, and only brushed lightly with a camel's hair pencil when necessary, and never touched by the fingers. Generally speaking, four, six, or even a greater number of cells are formed in each slider. When test objects are to be mounted in this way, only one or two cells should be made in each slider, which will lessen their liability to injury.

Fig. 30.

33. Another and an excellent method of mounting transparent objects is on slips of glass. A number of slips of glass of an uniform size should be procured, so that they can be fitted into a cabinet or otherwise. The dimensions to be employed are of course arbitrary; but it will be generally found, that the three following sizes are the most useful:—the first, 3-inches long and $\frac{7}{8}$ of an inch wide; the second, for smaller objects, 2-inches long and $\frac{5}{8}$ of an inch wide; and the third, $1\frac{1}{2}$ inches long and a quarter wide. The two first, when used for transparent objects, have a slip of paper pasted on one side with an aperture about one-third from the end; in the centre of which, beneath a plate of talc, the object is to be placed. It is better

to have a number of these blank sliders with the paper and talc pasted down at one end ready for use, for it often happens that many a valuable object is lost from not having a convenient receptacle for it when it presents itself.

34. In lieu of glass or ivory, a celebrated Microscopist uses small strips of mahogany veneer, with a hole bored through the centre, into which a piece of glass is fitted to place the object on. In either of these methods, the object is to be fastened to the glass by means of Canada balsam, the glass being warmed previously to its application. This renders objects extremely transparent and beautiful.

35. There are some objects, such for example as the larger wings of butterflies, which are not sufficiently transparent when mounted in either of the above ways. Mr. Pritchard has, however, devised a plan by which they may be exhibited with singular beauty and intensity of colouring. It consists in immersing the object completely in Canada balsam, and pressing it between two slips of thin glass, so as to exclude the air bubbles. The sides of the glass are then to be thoroughly wiped, so as to remove all superfluous moisture, and brushed over either with gold size or marine glue, the composition of which will be found explained further on. By this treatment, many objects which otherwise possess little interest, are rendered highly valuable, allowing the light to pass freely through them, exhibiting their structure, and presenting the most brilliant and superb colours. By this method also many cylindrical bodies are rendered perfectly distinct, the diffraction at the edges being in a great measure destroyed by the refractive power of the medium. In objects prepared in this way, we are able to perceive whether the cylindrical part be hollow or solid ; for when the former, they are often as finely injected as if by design.

It may be well to remark, with transparent objects generally, that, to observe all the minutiæ of the most delicate, particularly those which are called test objects, they should be placed upon a clear slip of glass without an intervening medium ; but if such must be used, they should be covered by a piece of very thin glass, as mica injures in some degree the rays of light proceeding from minute and delicate objects. It is only for the more common and least delicate forms of objects that the mica is useful.

36. Mounting Opaque Objects.—The smallest glass sliders, of which we have spoken, (section 33,) are exclusively used for opaque objects. On to one side of them is cemented, near the end, a piece of soft leather or cork, punched out into circles of a convenient size; the leather or cork being previously blackened, or covered with black paper. A pin run through the leather, holds the object conveniently. Sometimes these cylinders are made of ivory, but in all cases it must be remembered, that in order to render them fit as a back ground, they must be blackened. The darker the object the more black and sombre must be the mounting, to heighten the brilliancy of the object by the contrast. The best means of fixing the objects in this mounting, is a solution of isinglass and gum arabic in spirits of wine, which affords a strong and tough glue.

37. Mr. Cooper, the editor of the Microscopic Journal, remarks, that the plan of mounting opaque objects on a dead back ground, generally black paper is objectionable, on account of the small fibres on the surface of the paper reflecting some considerable portion of light. The plan he recommends for mounting minute objects, to be viewed either opaque or transparent, is simply by placing them on a piece of crown glass with a little weak gum-water, and surrounding them to the extent of a quarter of an inch or more with a rim of card-board sufficiently thick to prevent the object being removed or broken when another slide is placed either intentionally or otherwise upon it. By using the stop of the diaphragm the object is made opaque, and an even and uniform dark-coloured field is by this means obtained.

38. Mounting in Preservative Fluids.—Some objects, more particularly the microscopic infusoria, are generally deemed only to be interesting when seen alive, because from their peculiar structure they cannot be preserved for occasional inspection in the usual ways. This difficulty, however, may be removed, by preserving them in alcohol or other preservative fluid—a valuable resource, as it enables us to retain, with little injury, their general structure. By this means creatures which are new may be saved from entire demolition, and secured until their *genus, nature*, or usual *habitat* can be ascertained.

39. The method of mounting in alcohol or spirit of wine, is as

follows:—Take a slip of glass and cover it on one side with a coat of painter's white-lead, leaving a space in the middle large enough to contain the object to be mounted; when this coat is dry, add another, and proceed thus until a sufficient thickness is obtained for the enclosure of the object to be mounted. The next thing is to procure a clear piece of mica, free from veins and flaws, and rather smaller than the slip of glass. Fill the cavity with spirits of wine, place the object therein, and cover it with the plate of mica, which must be brought into close contact with the white lead, by gently pressing it with a smooth piece of wood from one extremity to the other, so as perfectly to expel the air bubbles. In a few days, the white lead will have become hard; and if the mica be sound, the enclosed specimen may be preserved for years. Instead of the mica, a piece of thin glass of the same size as the former may be laid on the surface of the white lead, and the edges kept together with marine glue.

40. Goadby's Method.—But the best and most valuable preservative fluid with which we are acquainted, is that discovered by Mr. Goadby, of which the following is the formula*:—

Bay Salt	4 ounces
Alum	2 ounces
Corrosive Sublimate ..	4 grains
Boiling water	2 quarts.

These ingredients are to be stirred well together, and when cold, strained.

Preparations immersed in this fluid keep their colour well, even those possessing a delicate rose tint, such as the blood corpuscules. In mounting objects for the microscope with this fluid, the following method may be adopted. If the object be flat, it will be only necessary to place it on a slip of glass, to drop on to it a little of the fluid, and then press on to it another piece of glass of a similar size—the superfluous moisture is then to be wiped from the edges of the two pieces of glass, and they are to be kept together by brushing the edges over either with gold size or marine glue. If the object be not

* This solution is equally valuable to the zoologist. No preservative fluid hitherto discovered, is equal to that of Mr. Goadby. Specimens thus put up, preserve all their beauty of form, flexibility, and natural colour.

flat, then the process described (section 39) must be resorted; Mr. Goadby's solution being substituted for the spirit of wine.

41. The marine glue is certainly the best cement for joining pieces of glass together, and it is also very useful in forming the cells for the reception of microscopic objects in lieu of the coatings of white lead, of which we have already spoken, (section 39.) It is made thus—one pound of caoutchouc is to be dissolved by maceration for several days in four gallons of coal naptha, and with one pint of this solution, two pounds of shellac are to be mixed by heat When the fusion is complete, it is to be poured out on a cold slate, and moulded into convenient forms for use. When cold, it is as hard as wax. It is applied by gently heating the glass, and then rubbing on the glue. So tenacious is its hold, that the joint will rarely, if ever give way,—the glass may be shivered to atoms, but the joints will remain firm as ever.

42. The following mode of preserving the crystals of salts, as permanent objects for the microscope, and for the exhibition by that instrument of the phenomena of polarized light, is due to the researches of Mr. Warrington. The method to be adopted in mounting the specimens, is as follows:—A warm saturated solution of the salt required is to be prepared, and a drop of it placed upon the glass slider on which it is intended to be permanently mounted, and allowed to crystallize; when a good group of crystals is obtained, the uncrystallized portion is to be cautiously removed,—this is best effected by drawing it gradually away in a small stream along the edge of the slider: having previously broken through that part of the crystalline ring adjacent to the edge, the salt is to be allowed to drain itself quite dry, by placing the slider on its end in a vertical position. It should next be examined, under the microscope, to ascertain the fitness of the crystals for the purposes required; because many salts separate from their solutions in crystals too thin to exhibit any prismatic colours when viewed by polarized light, appearing only of a pearly or silvery aspect, while others form in the opposite extreme, and are totally unfit, from their thickness, for investigation. Presuming, however, that the crystals are such as the investigator requires, the next step

is to drop on a small quantity of castor-oil—that which has been filtered cold must be employed, as otherwise it is liable to the same objection as olive-oil; and care must be taken that it covers the whole of the salt, and has displaced all the particles of atmospheric air that may have been adhering to the crystals. This having been done, a small piece of very thin glass is to be carefully placed on the surface of the oil, and any excess which may by this means have been pressed out cautiously removed by bibulous paper from the edges. The margin may then be covered by a coating of marine glue, a strong varnish of shellac or gold-size, and the crystals are permanently preserved for observation.' If varnish be used, one layer of it should be allowed to dry for twenty-four hours, before the next is applied; and during this time, the slides must be maintained in a flat position.

Chapter V.

MICROSCOPIC OBJECTS AND MEANS OF PROCURING THEM.

43. I have already observed, that every department of nature is full of objects of the greatest interest, when examined beneath the microscope. To all these it is impossible even to allude; but it is my intention, in this section of the work, to refer to some of the more interesting classes of objects, and the method in which they may be obtained and prepared for examination; thus, in fact, giving a kind of outline of the extent of the use of the microscope.

44.—Botanical Objects.—The elementary organs of plants require the assistance of the microscope to render them apparent. The forms of the elementary organs of plants are, 1, Cellular tissue; 2, Woody fibre, and 3, Vascular tissue. Cellular tissue composes the pith and soft parts of plants, and consists of distinct vesicles of various forms cohering together. Sections of the calycanthus floridus,

young branch of the misletoe, and the pith of the rubus odoratus, present all the varieties.

Woody fibre is best observed in vertical sections, cut either parallel or perpendicular to the medullary rays. It consists of a series of cells, which differ in exogens and endogens, and therefore sections of both are extremely interesting. What is called glandular woody fibre is peculiar to resinous woods, as the pine, which offers a good example. In this case the microscope has greatly assisted geology, by proving from this glandular structure that the coalbeds have been principally composed of ferns and pines.

Vascular tissue presents the most varied and interesting subject for microscopic examination; it consists of membranous tubes, internally furnished with fibre. The elder and asparagus give excellent specimens of this tissue.

45. Sections of Trees and Plants.— There is much tact required in preparing good and perfect sections of woods and plants. The specimens from which they are to be cut must be in a proper condition; the section should be of a uniform thickness, and the various tissues and vessels unbroken. Indeed, an instrument is required for the purpose of cutting them properly. The following is one which is at the same time convenient and efficacious. A represents a solid table of brass, about six inches long, four wide, and a quarter of an inch deep, with a guide or stay-piece, rising above the general surface at the back edge B. C is a hole through A, fitted with a short cylindrical socket, that extends below the under surface of A; it is close at the bottom, except that the screw passes through it. The head of this screw is made by a toothed wheel E, containing ten teeth, while the screw itself contains thirty threads to the inch. The use of this screw is to move up or down a brass cylinder with a square hole in it; the top of this is seen at D. The wheel, E, is kept in its place by the spring F. I I is a three-sided brass frame, which has a sharp razor-blade across it at I. K is the wooden stand to the whole. When used,

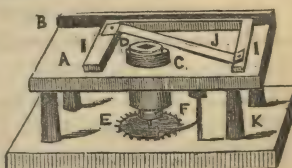


Fig. 31.

the wood to be cut is fixed tightly in the square hole D; the socket put into its place and adjusted by the screw below. The knife being then pushed forward will cut off a slice of wood; upon turning the wheel one tooth, and again moving the knife, a second slice will be obtained, and so on. These sections, if good, should float in spirits of wine. To form a proper idea of the structure of any plants, three sections should be made, viz:—one horizontal and two vertical, one of the latter being parallel to and the other perpendicular to the medullary ray.

46. The pollen or farina from the flowers of plants, the seeds of plants, the cuticles, and stomata or orifices in the cuticle, form a pleasing class of opaque objects. The spohrs of ferns, usually found in cells beneath the leaf, are likewise curious opaque objects. But one of the most interesting classes of botanical objects are the algæ which include the confervæ and fuci or sea weeds. In some of the latter plants, more particularly, the microscope enables us to observe the bursting of the cells, the release of the sporules, which become fringed with a number of cilia, by the motion of which the new being is able to traverse the water, until it finds a spot fitted for its future growth, to which it then becomes adherent. The same thing is observed with regard to the germ of the sponge: and here we have a remarkable similarity between the reproduction of a vegetable and animal being. Some of the small disjointed algæ are closely allied to animalcules, in which a circulation has been detected, and apparently a spontaneous motion. They are found in ditches and stagnant pools.

47. Fossil woods, when polished, are excellent opaque objects, and exhibit most of the characteristics of the original plant. But by far the most interesting specimens from this class of objects, are made by cementing very thin sections on to sliders, which may then be viewed either by reflected or transmitted light.

48. MICROSCOPIC SHELLS—Minute foramina, and other shells and remains, form an interesting series of objects to the lovers of microscopic research. The procuring of specimens of these minute fossils is generally considered difficult. But the following method recommended by Mr. Bowerbank * is simple, and within the reach of all:—" If the

* Microscopic Journal, vol. i. p. 21.

sand and dust, shaken out of the West Indian sponges into the bins or casks in which they are kept by dealers, be swept up and examined, it will be found to abound in minute shells, corals, and other interesting remains of marine animals; and among them many species of *foraminifera* are found, which appear very closely allied to many of the same family that I have seen in the fossil state. Species of echini, spicula of sponges, and an infinite variety of minute organic remains will reward the researches of the observer. The sponges themselves, in the state in which they are imported, are also well worthy of the trouble of a careful examination, especially those parts that are usually trimmed from the base, as being too full of impurities to be sold; many very beautiful specimens are thus found attached to the fibres of the sponge. I have not found many organic remains in the sand shaken out of the Turkey sponges; but it is probable that if the sand from such sponges, obtained from other localities, were to be carefully looked over, new and interesting objects would be the result of such an investigation."

49. Shells in Chalk.—Many, and probably all, white chalk rocks are the produce of microscopic coral animalcules, which are mostly quite invisible to the naked eye, possessing calcareous shells, of which more than one million are well preserved in each cubic inch, that is, much more than ten millions in one pound of chalk. The extreme minuteness of the chalk animalcules is strikingly proved by this, that even in the finest levigated whiting, multitudes of them are still present, and may be applied, without suffering change, to the most varied technical purposes; thus, in the chalk coating given to painted chambers, paper, or even glazed visiting cards (when not coated with white lead alone) may be seen a pretty mosaic of well-preserved moss-coral animalcules, but which are invisible to the naked eye; and thus our natural vision receives from such a surface the impression of the purest white, little dreaming that it contains the bodies of millions of self-existing beings of varied and beautiful forms, more or less closely crowded together.

The best method of examining into the animalcular composition of chalk, is that recommended by Ehrenberg,* which is as follows:—

* Ann. Natural History, June, 1841, p. 309.

"Place a drop of water upon a lamina of mica, and put into it of scraped chalk as much as will cover the fine point of a knife, spreading it out, and leaving it to rest a few seconds; then withdraw the finest particles, which are suspended in the water, together with most of the water, and let the remainder become perfectly dry. Cover this remainder, so spread out, with Canada balsam, and hold it over a lamp until it becomes slightly fluid, without froth. A preparation thus made seldom fails; and when magnified three hundred times in diameter, we see that the mass of the chalk is chiefly composed of minute well-preserved organisms." The fossil animalcules in chalk, according to Ehrenberg, amount to twenty-one genera, and forty species.

50.—Animalcules.—It is, perhaps, one of the easiest things connected with microscopic research, to procure animalcules. In all stagnant waters—in the scum of all decaying vegetable infusions—in fact, in all stagnant waters containing infusions of organised matters, these animalcules are to be obtained. The surface of infused liquors is generally covered with a thin pellicle which is easily broken, but acquires thickness by standing; the greatest number of animalcules are generally to be found in this superficial film. In some cases they are so extremely numerous, that it is necessary to dilute the infusions; but this is always to be done with *distilled* water, and this water should, for the sake of accuracy, be previously examined with the microscope before it is made use of; the neglect of this precaution has been a source of many errors. To place these minute animalcules under the microscope, the best method is by means of the feeding pin, represented in the annexed diagram. It consists of a glass thread inserted into

Fig. 32.

a convenient handle, the end of the glass being enlarged like the head of a common pin, which is to be dipped into the infusion. In this way a small drop of the fluid containing them may be placed on a slip of glass, and covered with a piece of talc, to prevent evaporation, and at

once subjected to examination. When it is desirable to examine the contents of different infusions, the feeding pin should be washed in distilled water between each dip, to prevent mixing. An infusion of common black pepper and of the red cabbage, if left exposed to the air for a few days, are excellent media for the production of animalcules.

51 There are some animalcules, to procure which requires greater care and more trouble ; such, for example, are the eels in paste. The following is the readiest method of obtaining these. Boil a little flour and water till it comes to the consistence of such a paste as is used by bookbinders or shoemakers. This paste should be made from flour and water only ; that of the shops, containing resin and other matters, is unfit for the purpose. Expose it to the air in an open vessel, and beat it from time to time with a wooden spatula, to prevent its surface becoming hard or mouldy. After a few days, particularly when the weather is warm, it will turn sour. Then if it be examined with attention, myriads of eels will be found on the surface. When they are once obtained, their motion on the surface of the paste will prevent any mildew, and it therefore requires no further attention. In like manner it will prevent its freezing in winter. If the paste be too thin, they will creep up the sides. In this case, a portion of very thick paste must be added to preserve them. When it is desirable to give them a fresh supply of food, it must not be put upon them, but they must be placed upon it.

To prepare them for the microscope take a few drops of clean water, and put a very small portion of the paste containing the eels into it. After it has stood a minute or two, the eels may be taken out and placed under the microscope, freed from a considerable portion of foreign matter.

52. Wheel Animalcule.—The Vorticella Rotatoria, or Wheel Animalcule, is another most interesting object for the microscope. In many works directions are given to search for them in leaden gutters, but the search of the microscopist in such situations will rarely be successful. The best method of raising and preserving them is as follows. Early in the spring fill a three-gallon jug with pure rain water, (not butt water, for the larvæ of the gnat tribe will then be mingled with them.)

This quantity suffices to fill a half-pint mug, and to keep it at the same level during the season. Then tie up a small portion of hay, about the size of the smallest joint of the little finger, trimming it so that it may not occupy too much room in the mug, and place it in the water; or the same quantity of green sage leaves will do. Every ten days the decayed portion should be gently removed with a piece of wire, and a fresh supply substituted. By either of these methods a good supply of wheel animalcules can always be kept up.

53. Polypi.—These animals, which are exceedingly interesting microscopic objects, are to be found upon all sorts of aquatic plants—upon branches of trees, pieces of board, rotten leaves, stones, and other substances that lie in the water. They should be sought for in the corners of ditches, puddles, and ponds, being generally driven into these with the pieces of wood or leaves to which they have attached themselves. They are seldom to be met with in winter; about the month of May they begin to appear and increase. They are generally found in waters which move gently, for neither rapid streams nor stagnant waters ever abound with them. I have drawn attention to these animals, because they are, probably, the most convenient for viewing the internal organization of animalcules. Their usual food assimilates so closely in colour to themselves, that it is impossible, under ordinary circumstances, to perceive the form of their digestive functions. Mr. Trembely, and, subsequently, Dr. Ehrenberg, have pursued the plan of feeding them with minutely divided solutions of coloured substances, such as indigo, carmine, and sapgreen, and by this means have ascertained the form of the digestive cavities in animalcules. It is essential that whatever colouring matter we employ should be pure and free from impurities, and that it be only mechanically not chemically soluble in water.

54. Mode of selecting Aquatic Larvæ and other Small Animals.—It is usual, for the purpose of thoroughly examining them, to obtain a quantity of the animalcules, found in stagnant pools or gentle streams, and to preserve them in convenient vessels. Although they are usually visible to the naked eye, yet it is difficult to select a specimen for examination, their organization being so delicate as not to allow of

their being touched. Two methods are usually adopted for this purpose, both of which are exceedingly convenient. The first instrument used is simply a glass tube at both ends. The upper end of it is to be held between the fingers, and the orifice closed by the thumb; the lower end is then to be immersed in the vessel of water, and the instant the animalcule required approaches the tube, the thumb is to be removed from the upper extremity, and the pressure of the atmosphere will force the water with the insect up the tube, when the thumb is again to close the upper apperture, and the tube with the object is to be removed. These tubes may be of different diameters to suit the various objects.

55. Some of the larvæ of insects are very delicate, and require very gentle means for removing them for examination. This may be very carefully done with the net spoon, an instrument similar to the accompanying outline. It consists of a wire bent in the peculiar form shown, and covered by a piece of muslin or net.

Fig. 33.

56. Insects.—The insect kingdom presents innumerable objects of interest to the microscopist. The antennæ or horns—the wings—wing-cases—the structure, number, and form of the eyes—the structure of their feet—their tongues and mouths, all form an interesting and necessary branch of enquiry, which will amply repay an attentive and minute examination. Most of these are opaque objects, with the exception of the wings, which in many cases may be viewed as transparent objects, particularly when prepared in the way already advised, (section 37.) To prepare these objects, great patience is required, inasmuch as they should be separated without injury from the body of the animal. In this dissection a very fine pair of scissors will be found of utility. It is requisite that their cutting edges should be exceedingly fine. Instruments for the purpose, can be obtained of most

optical instrument makers. Two very fine needles mounted in small handles are exceedingly useful in separating the various organs of insects; or the forceps, the knife, and point K, Fig. 13, will be found admirably adapted to aid the microscopist in his dissections, either before or while the object is beneath the miscroscope.

57. **Anatomical Injections.**—In the minute structure of the organs and tissues of higher animals, the microscope has been of the most essential service. The injection of these preparations is rather the province of works on anatomy; and I shall only here refer to a new method of injection, which, from its minuteness, is more particularly adapted to the microscope.

M. Doyere has devised a method for obtaining minute injections of the greatest utility in the examination of such structures beneath the microscope. The process consists in causing to enter in the same vessels, within a certain interval of time, two finely-filtered saline solutions, which, by double decomposition, give an abundant and opaque precipitate. The second solution is injected as soon as the first has passed from the arterial system into the venous and lymphatic systems.

M. Doyere has made a great number of experiments on the subject, from which he is led to prefer, to all others, the chromate of lead. He first injects a solution of chromate of potash; and it is to be remarked, that the order of injection is a point not to be neglected. A limpid solution of acetate or nitrate of lead is then injected, and a beautiful yellow injection is the result. A blue colour may be obtained by the precipitation of Prussian blue: brilliant red, of iodide of mercury; white, of carbonate or sulphate of lead from the usual solutions.

58. **Teeth and Shells.**—Sections of the teeth of various animals are beautiful microscopic objects. The principal substance of the teeth in almost all animals, is one called *Dentin*, characterised by minute tubular passages permeating it in a direction from the centre to the circumference. Considerable variation in the arrangement of these tubula is found in different groups of animals, which enable naturalists to determine, with great precision, by the microscopic examination of

even small fragments of ivory, the animal to which the tooth belonged. Shells also present beautiful appearances beneath the microscope. The shell of the echinus, or sea urchin, for example, is found to be composed of a network of calcareous matter, sometimes forming a series of plates parallel to each other, and connected with little pillars proceeding from one surface to another. In the spine, with which the animal is covered, this network has a most beautiful appearance. The shells of moluscs have been shown by the microscope not to consist of mere masses of calcareous matter, as a piece of limestone is, but are distinguished each by some peculiarity of structure, which the microscope exhibits to us. Primarily the shell of a molluscous animal is composed of cells of animal matter, in which are contained calcareous matter. In many cases, the shells are of a prismatic form, and the internal matter takes its shape from the cells. Here again the naturalist, by seeing the smallest fragment of shell, or even a little of the calcareous dust left when the membrane was discharged from it, can tell to what tribe of molluscs it has belonged.

59. Circulation in Animals and Plants.—One of the most interesting active phenomena exhibited by the microscope, is the circulation of the nutritious fluids in animals and plants. In the former, the globules of blood may be seen passing rapidly along the capillary ends of arteries into those of the veins when the intervening membrane is sufficiently diaphonous, as in the ear of the young mouse, the fins and tail of the carp, gold-fish, stickleback, tadpole, and of most small fish, and in the web between the toes of the frog, lizard, etc. etc. It need hardly be remarked, that in order to observe this phenomenon, the animals should be alive and fastened securely upon the stage of the microscope—the part to be examined, stretched before the object-glass, and a strong light directed through it.

Mr. Pritchard states, that in the Arachnoida, (spiders,) the circulation may be observed very distinctly, the currents of dark globules passing rapidly at each pulsation of the dorsal vessel. In the antennæ and wings of terrestrial insects, it has also been seen when they have just emerged from the chrysalis, as in the Perla Viridis, and Semblis Bilineata. In several aquatic larvæ and small curstacea, the circulating fluid appears to traverse the limbs, antennæ, and tails, and thence

moves along the dorsal vessel towards the head and down the sides of the body, in cavities and not distinct vessels; hence called diffused circulation. Even in the lowest forms of animal life, in the Acalephæ Infusoria and Polypi, it has been asserted, that the circulation has been observed; but these observations may be considered as liable to fallacy, on account of the prevalence of various kinds of ciliary currents in the interior of many of these animals. The striking analogy which these currents bear to those occurring in the stems of some plants, as Chara and Caulinia, seems to bring them under another class of phenomena, than those of the vascular circulation of the higher animals. The most favourable subjects for viewing this diffused circulation, are the larva of the ephemera—the larva of the hydrophilus—the water-flea (daphnia pulex.)

The circulation in plants termed cyclosis, is a revolution of the fluid contained in each cellule, and is distinct from those surrounding it. It can be observed in all plants in which the circulating fluid contains particles of a different refractive power or intensity, and the cellules of sufficient size and transparency. Hence all lactescent plants, or those having a milky juice, with the other conditions exhibit this phenomenon. The following aquatic plants are generally transparent enough to show the circulation in every part of them:—Nitella Hyalina, Nitella Translucens, Chara Vulgaris, and Caulinia Fragilis. In the frog-bit, (Hydrocharis,) it is best seen in the stipula of the leaves and the ends of the roots. In the spider-wort, (Trandescantia Virginica,) it is seen in the filaments surrounding the stamens of the flower. In the common groundsel, (Senecio Vulgaris,) it is said to be seen in the hairs surrounding the stalks and flowers.

60. In the foregoing pages, it has been the intention of the compiler to give a clear detail of the practical use of the microscope, and to explain its manipulation. As stated in the outset, this was the chief intention of the work; but it was found impossible to omit some reference to the wondrous revelations of this instrument. This sketch of the extent and variety of the discoveries effected by the microscope, is, from the limits of the work, necessarily a brief one. The continued use of the microscope, and the researches of naturalists into the infinitude of the organized creation, have been the means of

bringing to light great numbers of living beings, of whose existence but a few years back we had no reasonable proof. From the chilly regions of the Glaciers, with their coloured snow, to the pools of Egypt, with their living forms; from the waters of the Cattegat to the sunny waves of Mexico; from the Bergmehl of Finland to the brown mould of Newmarket; has the enquiring mind of the naturalist drawn evidence of the all-pervading principle of life. Forms, from whence the essence of vitality has long since departed, have given up their remnants from the chalk, and beings invisible to the naked eye of man have been summoned from their entombment in their flinty sarcophagi. The chaos of old systematists has passed away, and a structure of beauty has been formed from its heterogeneous materials. From the constant accessions to our knowledge of microscopic life, we cannot but acknowledge the truth of the poet's description—

"Full nature swarms with life—one wondrous mass
Of animals or atoms organised—
Waiting the vital breath, when parent Heaven
Shall bid his spirit blow. The hoary fen
In putrid streams emits the living cloud
Of pestilence. Through subterranean cells,
Where searching sunbeams scarce can find a way,
Earth animated heaves. The flowery leaf
Wants not its soft inhabitants. Secure,
Within its winding citadel, the stone
Holds multitudes. But chief the forest boughs,
That dance unnumbered to the playful breeze,
The downy orchard, and the melting pulp
Of mellow fruit, the nameless nation feed
Of evanescent insects. Where the pool
Stands mantled o'er with green, invisible,
Amid the floating verdure, millions stray.
Each liquid too, whether it pierces, soothes,
Inflames, refreshes, or exalts the taste,
With various forms abounds. Nor is the stream
Of purest crystal, nor the lucid air,
Though one transparent vacancy it seems,
Void of their unseen people. These, concealed
By the kind art of forming Heaven, escape

The grosser eye of man; for if the worlds
In world enclosed should on his senses burst,
From cates ambrosial, and the nectar'd bowl,
He would abhorrent turn; and in dead night,
When silence sleeps o'er all, be stunned with noise." *

* Thomson's Seasons—Summer.